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SPLITTAIL FECUNDITY AND EGG SIZE

FREDERICK FEYRER
Department of Biological Sciences
California State University, Sacramento
6000 J Street
Sacramento, California 95819

RANDALL BAXTER
California Department of Fish and Game
4001 North Wilson Way
Stockton, California 95205-2486

Fecundity and egg size of splittail, *Pogonichthys macrolepidotus,* are described from 17 specimens collected from February to April 1996. Splittail included in the study ranged from 216 to 328 mm standard length and were sampled from a broad area of their distribution. Ovaries accounted for a mean of 13.2% of total body weight. Splittail length accounted for nearly 40% of the variation in gonadosomatic index. Mean egg diameter was 1.2 mm and ranged from 1.0 to 1.5 mm. Egg size and splittail length were not related. Fecundity ranged from 28,416 to 168,196 ova. Mean relative fecundities were 261 ova/mm standard length and 163 ova/g total weight. One earlier study found slightly lower estimated fecundity, whereas another estimated fecundity to be significantly higher.

INTRODUCTION

The splittail, *Pogonichthys macrolepidotus,* is a cyprinid endemic to the Sacramento-San Joaquin Estuary. It is relatively large (maximum length about 400 mm) and long lived (age >5 years) for a cyprinid (Moyle 1976, Daniels and Moyle 1983). Splittail are omnivorous and tolerant of relatively high salinity (Caywood[1] 1974, Young and Cech 1996). A strong positive relationship exists between year-class strength of splittail and freshwater outflow in the estuary (Daniels and Moyle 1983, Sommer et al. 1997). Although the splittail possesses life history traits well suited for the highly variable estuarine environment, they are currently a candidate species pursuant to the U.S. Endangered Species Act of 1973 (U.S. Fish and Wildlife Service 1994).

Splittail prefer shallow, tidal freshwater, and low-salinity habitats typical of Suisun Marsh, Suisun Bay, and the Sacramento-San Joaquin Delta (Meng and Moyle 1995). From March to May, adults migrate from Suisun Bay and the delta upstream to spawn in flooded terrestrial habitats (Caywood[1] 1974, Sommer et al. 1997).

[1] Caywood, M.L. 1974. Contributions to the life history of the splittail *Pogonichthys macrolepidotus* (Ayers). M.S. Thesis, California State University, Sacramento, California, USA.

Splittail eggs are adhesive (Caywood[1] 1974) and are deposited on substrates in clusters (Wang[2] 1986). Juveniles migrate or are washed downstream by river flows into the shallow, highly productive areas of the lower estuary, such as Suisun Bay and Suisun Marsh. Both male and female splittail mature at 180–200 mm standard length (SL) (Caywood[1] 1974, Daniels and Moyle 1983).

Recent studies of splittail have focused on population status and geographic distribution (Meng and Moyle 1995, Sommer et al. 1997) and physiological tolerances (Young and Cech 1996). The reproductive capacity of splittail, measured here as fecundity, has only received limited study by Caywood[1] (1974) and Daniels and Moyle (1983). These studies were based on small sample sizes (n = 8 for Caywood and n = 20 for Daniels and Moyle) and produced different results. For these reasons, we chose to re-examine the fecundity and egg size of splittail during the 1996 spawning season and compare our findings with those of the 2 earlier studies.

METHODS

Collection and Processing

From 28 February to 2 April 1996, we collected 17 female splittail from a broad geographical area (Fig. 1). Gill nets captured 12 at Clifton Court Forebay and 2 at Sherman Lake. Hook and line captured 2 at Miller Park and 1 at Walnut Grove. All fish were immediately dispatched and placed on ice, then frozen later in the day.

Frozen splittail were defrosted, measured to the nearest millimeter SL and weighed (TW) to the nearest 0.1 gram. Ovaries were removed, individually weighed to the nearest 0.1 g and preserved in 10% formalin. Total ovary weight (TOW) was the sum of right and left ovary weights.

Egg Size, Gonadosomatic Index, and Fecundity

Sizes of 10 randomly selected ova from each of 15 splittail were measured to the nearest 0.1 mm with an ocular micrometer on a binocular dissecting microscope. Egg size of the remaining 2 splittail could not be measured because of poor ovary preservation. The longest axis of each ova was measured because ova were not round. We determined gonadosomatic index (GSI) by expressing TOW as a percentage of total body weight (TW): GSI = 100(TOW/TW).

Total fecundity was estimated by counting the number of ova in 3 weighed subsamples (anterior, median, and posterior), calculating mean number of ova per gram, and multiplying the mean by the total preserved ovary weight. Relative fecundity was expressed as the number of ova/mm SL or the number of ova/g TW.

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[2] Wang, J.C.S. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: A guide to the early life histories. Technical Report No. 9, prepared for the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary.

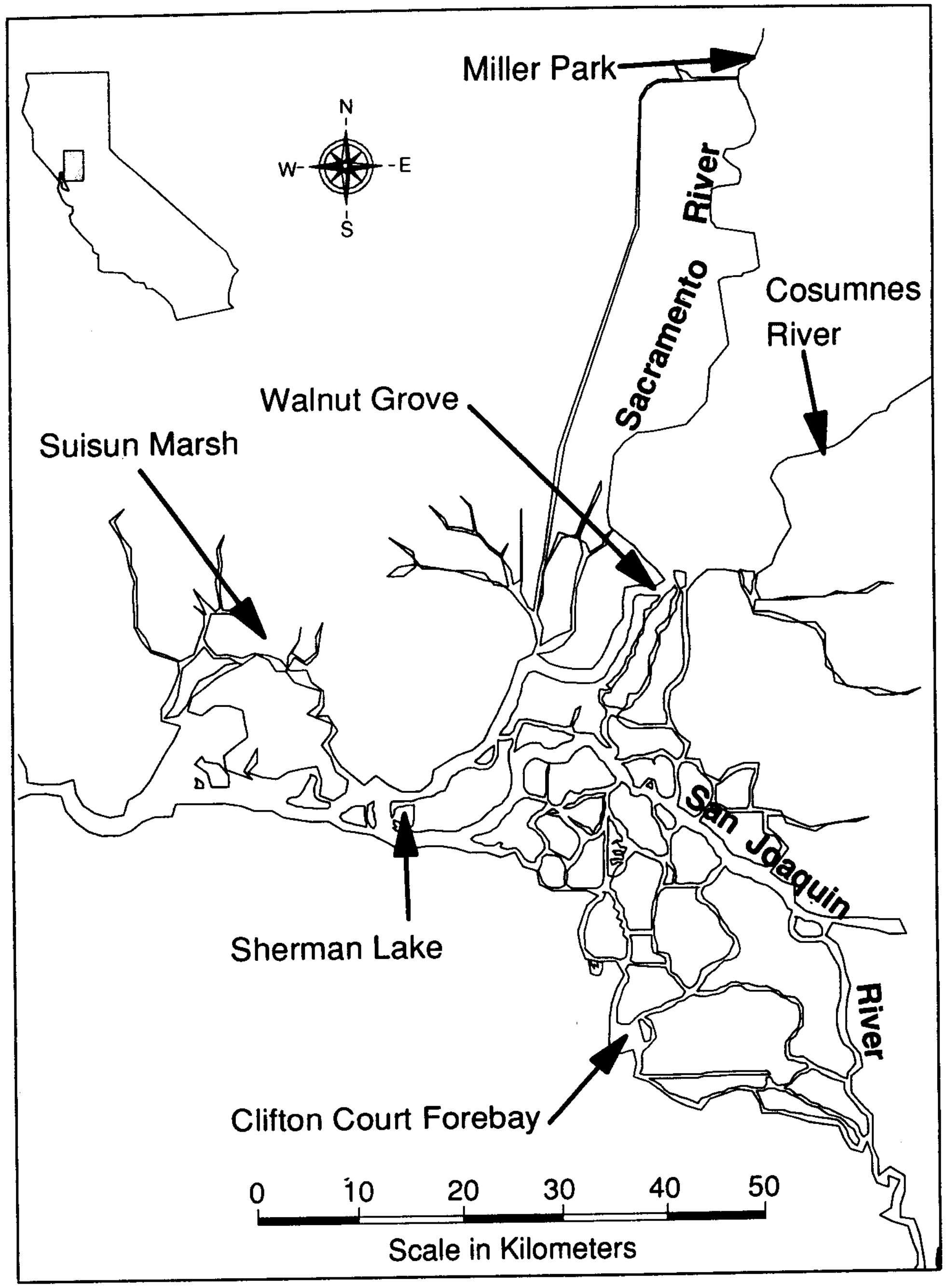

Figure 1. Map of the Sacramento-San Joaquin Estuary showing splittail sampling locations.

Data Analysis

Simple linear regression analyses were used to determine if egg size, GSI, and fecundity varied as functions of length and if fecundity was a function of total weight. Plots of fecundity on length and total weight indicated that each was an exponential function, so these variables were log transformed prior to regression analyses. A paired t-test was used to test for consistent weight asymmetry between left and right ovaries.

RESULTS

Mature female splittails collected ranged from 216 to 328 mm (mean = 264, SD = 30.6, n = 17). Egg size ranged from 1.0 to 1.5 mm (mean = 1.2, SD = 0.10, n = 150) (Table 1), but did not vary with female length ($r^2 = 0.13$, $P > 0.05$) (Fig. 2). Ovaries accounted for up to 20.3% (mean = 13.2, SD = 3.23, n = 17) of TW (Table 1).

Table 1. Summary data of all splittail examined for fecundity from the current study, Caywood[1] (1974), and Daniels and Moyle (1983). Locations are: WG–Walnut Grove, CCF–Clifton Court Forebay, MP–Miller Park, SL–Sherman Lake, CR–Cosumnes River (Caywood[1] 1974), and SM–Suisun Marsh (Daniels and Moyle 1983). Measurements in mm fork length (FL) (Caywood[1] 1974) were transformed into mm standard length (SL) for statistical comparison: $SL = 0.92FL - 12.08$, $r^2 = 0.99$, $P < 0.05$, n = 17.

Collection date	Location	SL (mm)	TW (g)	Ovary weight(g)	Fecundity	GSI	Egg size(mm)
2/09/96	WG	273	503	69.00	110,600	13.6	1.25
2/21/96	CCF	246	343	33.50	51,491	9.7	1.12
2/21/96	CCF	328	744	151.40	168,196	20.3	–
2/21/96	CCF	250	339	26.20	28,416	7.7	1.10
2/21/96	CCF	270	481	55.40	45,085	11.5	1.11
2/21/96	CCF	297	642	94.00	97,660	14.6	1.34
2/21/96	CCF	315	644	104.30	113,898	16.1	–
2/21/96	CCF	245	309	36.60	44,960	11.8	1.26
2/21/96	CCF	258	409	50.30	53,590	12.2	1.27
2/21/96	CCF	283	504	77.20	81,776	15.3	1.30
2/21/96	CCF	227	266	35.50	67,210	13.3	1.12
2/21/96	CCF	250	336	25.60	52,744	7.6	1.29
2/21/96	CCF	274	485	84.30	74,655	17.4	1.33
3/12/96	MP	231	259	35.70	39,911	13.7	1.28
3/12/96	MP	294	558	76.60	94,123	14.8	1.28
4/02/96	SL	249	302	44.70	53,900	11.8	1.22
4/02/96	SL	216	211	24.90	35,609	–	1.28
2/06/74	CR	313	–	83.87	54,555	–	–
2/06/74	CR	323	–	90.93	73,185	–	–
2/06/74	CR	300	–	75.49	75,589	–	–
2/06/74	CR	290	–	64.40	48,062	–	–
2/06/74	CR	287	–	55.54	44,802	–	–
2/06/74	CR	287	–	61.27	43,211	–	–
2/06/74	CR	263	–	28.97	25,991	–	–
2/06/74	CR	242	–	20.90	23,177	–	–
–	SM	302	–	–	265,954	–	–
–	SM	260	–	–	203,385	–	–
–	SM	232	–	–	137,491	–	–
–	SM	258	–	–	153,359	–	–
–	SM	249	–	–	154,973	–	–
–	SM	223	–	–	93,626	–	–
–	SM	248	–	–	103,020	–	–
–	SM	260	–	–	150,206	–	–

We did not observe a time trend in GSI ($r^2 = 0.003$, $P > 0.05$). However, a significant positive relationship existed between GSI and female length (Fig. 3), in which length accounted for about 40% of the variation in GSI ($r^2 = 0.39$, $P < 0.05$; GSI = 0.06SL − 4.30). There was no significant weight asymmetry between left and right ovaries (t = 2.10, $P > 0.05$, n = 17), but weight differences of as much as 22 g were measured.

Fecundity ranged from 28,416 to 168,196 ova (mean = 71,401, SD = 36,171, n = 17) (Table 1). Mean relative fecundity was 261 ova/mm SL (SD = 103.2) and 163 ova/g TW (SD = 42.3). Total fecundity varied significantly as a function of female length ($r^2 = 0.67$, $P < 0.05$; fecundity = $0.0004SL^{3.40}$) (Fig. 4) and as a function of total weight ($r^2 = 0.66$, $P < 0.05$; fecundity = $107.39TW^{1.06}$).

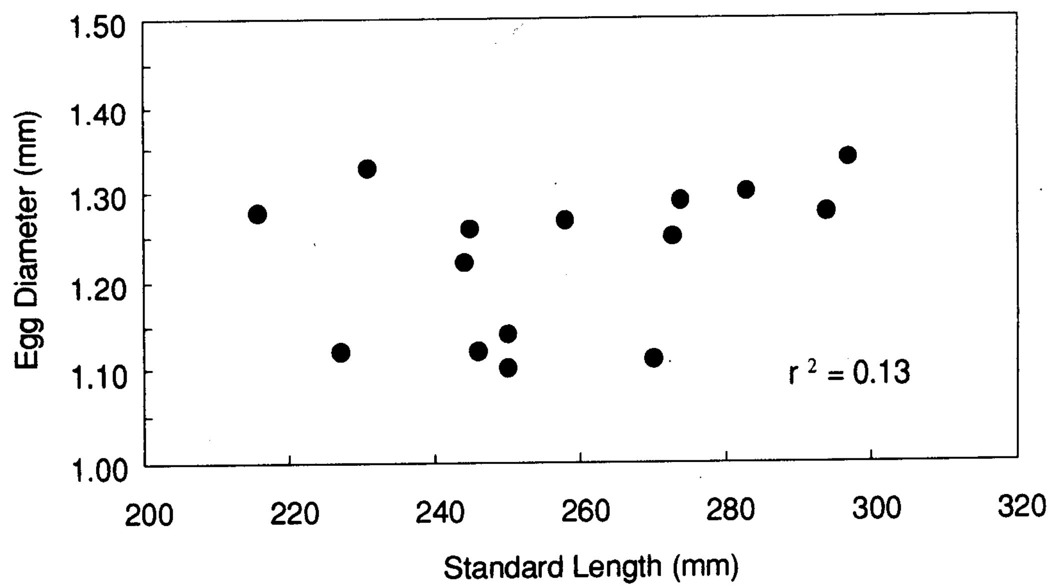

Figure 2. Relationship between mean egg diameter and splittail standard length.

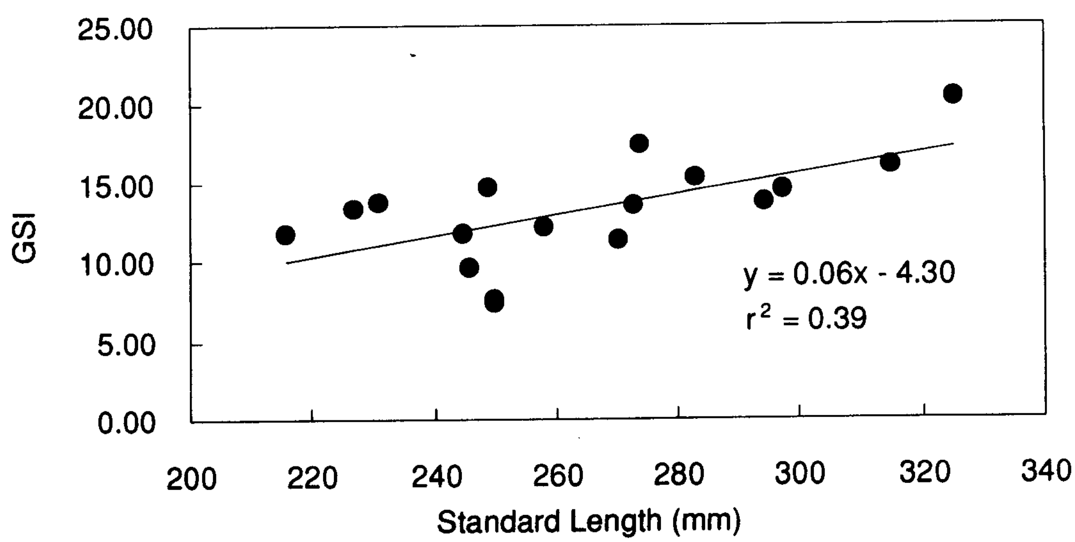

Figure 3. Relationship between GSI and splittail standard length.

DISCUSSION

The splittail is highly fecund compared to other native species. It averages 261 ova/mm SL and has a maximum fecundity >150,000 eggs. In contrast, delta smelt, *Hypomesus transpacificus*, an annual species also endemic to the Sacramento-San Joaquin Estuary, averages $\leq$35 ova/mm SL; maximum fecundity is only 2,500 eggs (Moyle et al. 1992). Maximum fecundity estimates for other species native to the estuary include 10,932 for Sacramento sucker, *Catostomus occidentalis* (Burns 1966a); 17,730 for Sacramento pikeminnow, *Ptychocheilus grandis* (Burns 1966b); 26,000 for hitch, *Lavinia exilicauda* (Nicola[3] 1974); and 124,720 for Sacramento perch, *Archoplites interruptus* (Mathews[4] 1962). However, Murphy (1950) reported a Sacramento blackfish, *Orthodon microlepidotus* (collected from Clear Lake, Lake County, California) with an estimated 350,000 eggs.

The high fecundity of splittail is necessary because it exhibits no parental care (Wang[2] 1986), prefers to deposit eggs on flooded terrestrial vegetation (Caywood[1] 1974) that can often become exposed to air when floods recede, and lives in a highly dynamic environment that is subject to dramatic annual fluctuations in the quantity of suitable spawning habitat. High fecundity and small egg size are common strategies for reproduction in harsh environments (Bagenal 1978).

Our estimates of splittail fecundity differ from those of 2 earlier studies (Table 1). We were able to obtain data for all 8 splittail examined by Caywood[1] (1974), but only for 8 of 20 splittail examined by Daniels and Moyle (1983), for statistical comparison (Table 1). After a significant ANOVA ($F = 37.57$; $df = 2, 30$; $P < 0.05$), Tukey's multiple comparison test indicated that mean eggs/mm SL reported by Daniels and Moyle (1983) was significantly higher than that found by the other studies (Fig. 4). No GSI or egg size data are available for splittail examined for fecundity in the earlier studies. Caywood[1] (1974) reported GSI values within the range of the current study, but for splittail other than those for which fecundity was estimated. Daniels and Moyle (1983) only reported a maximum GSI (18%), which was surprisingly lower than the maximum reported by the other 2 studies considering their significantly higher fecundity estimates. Caywood[1] (1974) did not measure egg size, whereas Daniels and Moyle (1983) measured an insufficient number of egg diameters to use in analysis.

The difference in fecundity estimated between Daniels and Moyle (1983) and the other 2 studies is striking. To further investigate the discrepancy, we estimated GSI for the Daniels and Moyle (1983) data (Table 1) based upon our egg weights and the splittail length-weight relationship. The resulting GSI estimates ranged from 37% to well over 50%. However, Daniels and Moyle (1983) reported a maximum GSI of

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[3] Nicola, S.J. 1974. The life history of the hitch, *Lavinia exilcauda* Baird and Girard, in Beardsley Reservoir, California. California Department of Fish and Game, Inland Fisheries Administrative Report No. 74-6.

[4] Mathews, S.B. 1962. The ecology of the Sacramento perch, *Archopolites interruptus*, from selected areas of California and Nevada. M.A. Thesis, University of California, Berkeley, California, USA.

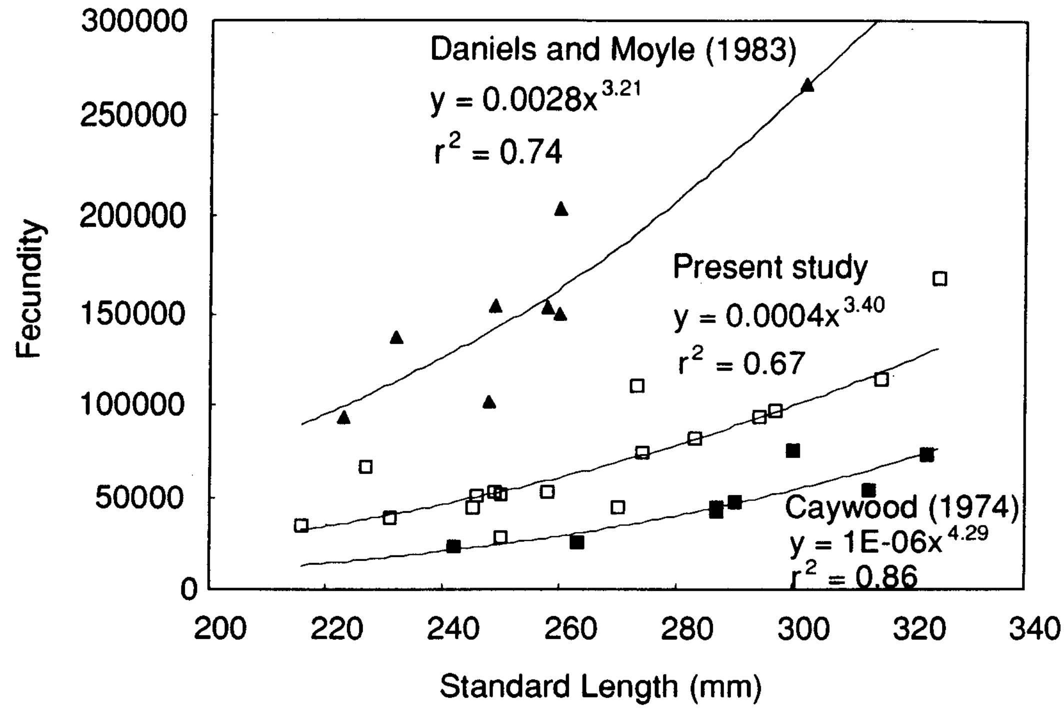

Figure 4. Relationship between fecundity and splittail standard length from 3 independent studies. Daniels and Moyle's estimates (1983) are significantly higher than those of the 2 other studies ($P < 0.05$).

only 18%. If these data are correct, average egg size of the Daniels and Moyle (1983) splittail would have to be at least 50% smaller (mass or volume) than that of our study. Daniels and Moyle (1983) estimated fecundity for splittail collected throughout the calendar year. Splittail collected before the spawning season may have included ova that never matured and were not spawned. However, it seems unlikely that at least 50% of splittail eggs do not mature and are not spawned. If correct, the significant difference in splittail fecundity reported by Daniels and Moyle (1983) may reflect regional or annual natural variability.

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